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Subjective Reactions to Atropine/2-PAM Chloride and Heat While in Battle Dress Uniform and in Chemical Protective Clothing

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Subjective reactions and symptomatology were assessed during continued exposure to combinations of atropine (2 mg) and 2-PAM chloride (600 mg), heat and humidity at 95 °F (35 °C) with 60% relative humidity (RH), and wearing of either the U.S. Army battle dress uniform (BDU) or impermeable chemical protective clothing (MOPP-IV). Reported symptoms were due primarily to heat rather than to drug effects, but some visual and somesthetic reactions typical of atropine were also noted. Elevated heat stress caused by wearing MOPP-IV at 95 °F (35 °C) with 60% RH significantly increased the frequency and severity of reported symptoms, compared to a parallel study in which only BDUs were worn under equivalent heat and humidity conditions. At 95 °F (35 °C) with 60% RH, participants were able to complete the 6 hr of testing wearing BDUs, but they lasted only 2 hr in MOPP-IV. Claustrophobic reactions due to encapsulation in MOPP-IV, which have been reported in other studies, were not observed in this study.

The possibility that nerve agents may be deployed in future warfare has led the U.S. armed services to develop means for effective protection and treatment of military personnel in case of such exposure. The current U.S. armed forces nerve agent antidote is a combination of atropine sulfate (atropine) in 2-mg dose units and pralidoxime chloride (2-PAM) in 600-mg dose units administered by paired intramuscular injections. Although these drugs provide good physical protection, they also have side effects that

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could lead to adverse subjective reactions and impaired performance (O'Leary, Kunkel, & Jokes, 1961; Taylor, 1980; Vojvodic & Boskovic, 1974).

The major physiological reactions to atropine alone (Calesnick, Christensen, & Richter, 1967; Cullumbine, McKee, & Creasey, 1955; Marzulli & Cope, 1950), and to atropine in combination with heat stress (Kolka, Holden, & Gonzalez, 1984; Kolka, Stephenson, Bruttig, Cadarette, & Gonzalez, 1987; Kolka, Stephenson, & Gonzalez, 1986), have been identified. Effects on psychological, perceptual, and cognitive behavior are less clear, although some performance-oriented studies have been conducted (see, e.g., Baker et al., 1983; Moylan-Jones, 1969; Penetar & Henningfield, 1986; Wetherell, 1980). The physiological effects of 2-PAM alone and in combination with atropine have also been studied (see, e.g., Holland, Kemp, & Wetherell, 1978; Robinson & McMichael, 1970). Much less is known about associated psychological and perceptual effects (Haegerstrom-Portnoy, Jones, Adams, & Jampolsky, 1987; Headley, 1982), although such knowledge is essential in view of their paired use as the standard nerve agent antidote.

Chemical warfare in hot or hot and humid tropical and desert areas will cause other problems that inhibit the successful use of nerve agent antidotes. Heat stress under such conditions will increase in severity when troops wear chemical protective clothing, specifically the Mission Oriented Protective Posture (MOPP) ensemble. Based on a modular concept, the MOPP ensemble provides successively greater degrees of chemical protection through increased levels of encapsulation, termed MOPP-I, -II, -III, and -IV. At MOPP-IV (i.e., total encapsulation), heat and body moisture trapped inside the ensemble rapidly accumulate and interfere with performance, even under cool ambient conditions.

It is conceivable that chemical threats (e.g., surprise attacks, premature injection by mistake, or physical damage to the MOPP-IV ensemble sufficient to break encapsulation) could occur that would cause personnel to self-administer nerve agent antidote while wearing the MOPP-IV ensemble. In such situations, troops would be subjected to a greatly increased heat/humidity stress load combined with the effects of nerve agent antidote. On the other hand, situations could also occur in which personnel would receive atropine/2-PAM in hot and humid conditions while wearing only the BDU, the current field uniform. There are virtually no systematic data suitable for making overall comparisons of subjective and psychological reactions under the various combinations of circumstances.

To obtain such information, a study was conducted to systematically assess both the separate and combined effects of heat exposure, standard atropine/2-PAM dosage, and wearing of both the BDU and MOPP-IV

ensembles on a variety of psychological, rational, and cognitive tasks involved in military performance. The performance tasks included visual acuity, phoria, stereopsis, visual contrast sensitivity, speech intelligibility, arm–hand steadiness, voluntary muscle tremor, gross manual dexterity, fine dexterity, body mobility and coordination, visual reaction time, simulated rifle marksmanship, eye–hand coordination, tapping, verbal reasoning, and digit–symbol substitution. The overall project consisted of two separate studies that were identical, aside from one exception. In Study 1, the participants wore the BDU ensemble; in Study 2, the participants wore MOPP-IV. For a condensed summary of this project, see Kobrick, Johnson, and McMenemy (1988). The present article is a detailed review of the symptomatic, mood, and subjective reactions reported by the participants.

STUDY 1. EFFECTS OF ATROPINE/2-PAM AND HEAT ON SYMPTOMATIC, MOOD, AND SUBJECTIVE REACTIONS WHILE WEARING THE BDU ENSEMBLE

Method

Participants. Fifteen male soldiers, ages 18 to 32 years, were screened medically and were tested for normal vision and hearing. They were briefed on the nature of the study and its potential hazards; they then read and signed a volunteer agreement of informed consent before being allowed to participate.

Procedure. The soldiers were trained intensively 6 hr per day for 5 consecutive days on the group of performance tasks listed earlier. Thereafter, they performed the tasks on 4 separate test days, each day corresponding to one of the following experimental test conditions: (a) control—that is, a saline placebo at 70 °F (21.1 °C) with 30% relative humidity (RH), (b) drug only—that is, 2 mg of atropine and 600 mg of 2-PAM at 70 °F (21.1 °C) with 30% RH, (c) ambient heat only—that is, a saline placebo at 95 °F (35 °C) with 60% RH, and (d) drug and ambient heat—that is, 2 mg of atropine and 600 mg of 2-PAM at 95 °F (35 °C) with 60% RH. On each test day, the soldiers received either the assigned combination of atropine and 2-PAM or equivalent volumes of saline placebo, injected into the thigh muscle using 22-gauge syringes. Atropine was administered by one injection. Because 2-PAM causes discomfort at the injection site, the required 600-mg dose was divided into two 300-mg units, one injected into the thigh muscle of each leg. Drug conditions were assigned on a double-blind basis; however, for safety reasons, a medical monitor presiding over the study

knew the identities of both drug and placebo participants. Test days were separated by at least 3 days to ensure adequate recovery from the preceding drug conditions. Testing began each day approximately 30 min after drug administration.

All participants were scheduled to complete three cycles of the group of performance tasks on each testing day. They continued to perform until they either withdrew voluntarily or were removed by the medical monitor for exceeding medical safety criteria—pulse rate of 160 beats per minute or higher for 5 min and/or having a rectal temperature in excess of 102.2 °F (39 °C). The three cycles began at standard 2-hr intervals in order to maintain overall uniformity of daily heat exposure. Participants were allowed to drink water ad lib from standard military canteens; however, lunch and snacks were not allowed.

Three paper-and-pencil tests were administered periodically during the course of each experimental session: (a) the U.S. Army Research Institute of Environmental Medicine Environmental Symptoms Questionnaire (ESQ; Kobrick & Sampson, 1979), as modified by Kobrick et al. (1988); (b) the Profile of Mood States (POMS; McNair, Lorr, & Droppelman, 1981); and (c) the Brief Subjective Rating Scale (BSRS; Johnson, 1981).

The ESQ is a self-rating inventory designed to sample subjective reactions and medical symptomatology of individuals during exposure to environmental and other stressors. It contains 68 statements describing various symptomatic reactions for which the respondent rates his or her experienced severity on a scale ranging from *not at all* (0) to *extreme* (5). The POMS is a factor-analytically derived rating scale consisting of 65 items intended to assess six mood states (tension, depression, anger, vigor, fatigue, and confusion). The BSRS is designed to measure subjective feelings of warmth, discomfort, and tiredness on separate rating scales by selection of descriptive words or phrases. Warmth is rated on a 7-point scale ranging from *cold* (1) to *hot* (7). Discomfort is rated on a 4-point scale ranging from *not at all uncomfortable* (1) to *very uncomfortable* (4). Tiredness is rated on a 4-point scale ranging from *not at all tired* (1) to *very tired* (4).

The ESQ and POMS were administered once at the end of each daily session to survey individual subjective reactions, feelings, and temperament patterns during exposure to the experimental conditions. The BSRS was administered once at the beginning of each session (30 min after injection) and once at the end of each of the three cycles within the session (150, 270, and 390 min after injection).

Results and Discussion

ESQ. To survey the overall incidence of reported symptoms, the group mean ratings for each of the 68 ESQ items were calculated for each of the

four test conditions. The separate ESQ items were then arrayed sequentially in descending order of group mean rating magnitude for the control condition—that is, at 70 °F (21.1 °C) with 30% RH—on the assumption that this array represented the most likely order of relative frequency of symptom occurrence under optimum test conditions. The mean rating values were then arrayed for the other three test conditions, using the same order of ESQ items as for the control condition. This arrangement is summarized in Table 1, along with short statements of the respective ESQ items. All rating values are shown for the optimum control condition; only values of 1.00 or more are shown for the three stressful test conditions because they represent a minimal noxious reaction.

Comparison of the ratings in Table 1 shows similarities and differences among the four test conditions in the incidence of symptoms. Four items were rated 1.00 or higher in all conditions: hungry (Item 68), felt good (Item 67), alert (Item 66), and tired (Item 56). This probably reflects the arousing aspects and the endurance demands of being involved in the project, as well as hunger due to the omission of lunch. The fewest severe negative symptoms (i.e., ratings of 2.00 or higher on any items, except for Items 66, 67, or 68) clearly occurred under the control condition. The two heat conditions generated more symptoms and different patterns of incidence. One can discern effects probably due to atropine/2-PAM alone: high ratings on dry mouth (Item 49), thirsty (Item 55), and a moderate rating on sore throat (Item 50). Thirsty (Item 55) was highly rated in all three stressful conditions, probably due to heat exposure and to drug effects. The effects of heat alone are shown by high ratings on felt warm (Item 30), feet sweaty (Item 32), sweating all over (Item 33), and a moderate rating on thirsty (Item 55). One can also see that the most severe test condition (i.e., drug combined with heat) produced the greatest number of high ratings. Headache (Item 2) and lightheadedness (Item 1) were reported in this condition only. Also reported were heat effects (Items 30 and 33), occurrence of dry mouth (Item 49), and thirst (Item 55).

POMS. Separate two-way (Temperature × Drug) analyses of variance (ANOVAs) were performed on the individual ratings for each of the six POMS scales to identify any significant main effects attributable to the test conditions. The results of these analyses showed significant main effects for temperature, acting to increase tension, $F(1, 14) = 5.36$, $p < .05$, and reduced vigor, $F(1, 14) = 5.44$, $p < .05$. A significant main effect due to drug, reduction of vigor, was also found, $F(1, 14) = 19.46$, $p < .01$.

BSRS. Separate three-way ANOVAs (Temperature × Drug × Cycle) for repeated measures were conducted on the individual ratings for each of the BSRS scales.

TABLE 1
Group Mean Ratings on ESQ Items for Each Task Condition With BDU

Item No.	Description of Item	Group Mean Ratings: 70 °F (21.1 °C) 30% RH Control	70 °F (21.1 °C) 30% RH Drug Only	95 °F (35 °C) 60% RH Heat Only	95 °F (35 °C) 60% RH Drug and Heat
68	I was hungry	3.40	3.00	3.27	2.87
67	I felt good	2.73	1.60	1.93	1.20
66	I felt alert	2.13	1.47	2.20	1.33
56	I felt tired	1.20	1.07	1.00	1.87
57	I felt sleepy	0.93	1.20		1.93
36	I felt chilly	0.93	1.07		
35	My feet were cold	0.80			
34	My hands were cold	0.80			
37	I was shivering	0.53			
25	I had gas pressure	0.53			
7	Coordination was off	0.47			
51	I was coughing	0.40			
49	My mouth was dry	0.40	3.53		3.27
1	I felt lightheaded	0.40			1.07
2	I had a headache	0.33			2.13
19	I felt weak	0.33			
64	I was bored	0.33			
47	I had a runny nose	0.33			
50	My throat was sore	0.27	1.20		
4	I felt dizzy	0.20			
20	My legs or feet ached	0.20			
6	My vision was dim	0.20			
46	My nose felt stuffed up	0.20			
59	Concentration was off	0.20			
29	Urinate less than usual	0.20			
17	I had stomach cramps	0.20			
40	My eyes felt irritated	0.20			
60	Was more forgetful	0.20			
23	I had a stomachache	0.20			
39	Skin burning or itchy	0.13			
41	My vision was blurry	0.13			
53	I felt sick	0.13			
63	I felt restless	0.13			
61	Felt worried/nervous	0.13			
22	My back ached	0.13			
55	I was thirsty	0.13	2.73	1.07	2.27
13	I had a chest pain	0.13			
45	My ears were ringing	0.13			
24	Felt sick to stomach	0.13			
62	I felt irritable	0.07			
18	Muscles tight or stiff	0.07			

(Continued)

TABLE 1 *(Continued)*

Item No.	Description of Item	Group Mean Ratings: 70 °F (21.1 °C) 30% RH Control	70 °F (21.1 °C) 30%RH Drug Only	95 °F (35 °C) 60% RH Heat Only	95 °F (35 °C) 60% RH Drug and Heat
52	I lost my appetite	0.07			
21	Hand/arm/shoulder ache	0.07			
15	Hands shaking or trembling	0.07			
30	I felt warm	0.07		3.07	2.40
5	I felt faint	0.07			
42	Ears blocked up	0.07			
38	Parts of body numb	0.07			
32	Feet were sweaty	0.07		2.00	
16	I had a muscle cramp	0.07			
3	I felt sinus pressure	0.07			
44	I could not hear well	0.07			
27	I felt constipated	0.00			
31	I felt feverish	0.00			
48	I had a nose bleed	0.00			
14	I had chest pressure	0.00			
12	Heart was pounding	0.00			
11	Heart was beating fast	0.00			
10	It hurt to breathe	0.00			
9	It was hard to breathe	0.00			
8	I was short of breath	0.00			
54	I felt hung over	0.00			
33	Sweating all over	0.00		3.40	3.13
65	I felt depressed	0.00			
43	My ears ached	0.00			
28	Urinate more than usual	0.00			
26	I had diarrhea	0.00			
58	I could not sleep well	0.00			

Note. Only ratings of 1.00 or greater are shown for the drug only, heat only, and drug and heat conditions.

On the Tiredness scale, significant main effects were found for drug, $F(1, 14) = 6.93$, $p < .02$, and for cycle, $F(3, 42) = 3.39$, $p < .05$, indicating that the soldiers felt more tired under the drug-only condition than they did under the control condition, and that they were least tired during pretest. A significant Temperature × Drug interaction, $F(1, 14) = 10.26$, $p < .01$, was also found, suggesting further that although the soldiers felt equally as tired under the control and drug-only conditions, they felt more tired in the drug and heat condition (mean rating = 2.5) than under the control condition (mean rating = 1.8).

On the Discomfort scale, significant main effects were found for temper-

ature, $F(1, 14) = 45.16, p < .001$, cycle, $F(3, 42) = 3.66, p < .02$, and for a Temperature × Cycle interaction, $F(3, 42) = 4.17, p < .02$, indicating that the soldiers felt more uncomfortable at 95 °F (35 °C) than at 70 °F (21.1 °C); also, their levels of discomfort increased with continued exposure. A significant main effect was also found for drug, $F(1, 14) = 8.37, p < .02$, indicating that they felt more uncomfortable under the two drug conditions than under the control and heat-only conditions.

On the scale rating warmth, a significant main effect was found for temperature, $F(1, 14) = 67.04, p < .001$, and for the Temperature × Cycle interaction, $F(3, 42) = 9.81, p < .001$, reflecting the overall continuing effect of heat exposure on thermal sensation, despite the lack of corresponding significance of the cycle effect itself.

In general, the BSRS data show that the soldiers felt more uncomfortable and more tired under the two drug conditions than under the two placebo conditions. At 95 °F (35 °C), they felt hot and uncomfortable, as one would expect, and subjective feelings of tiredness were significantly increased by administration of atropine/2-PAM.

The results of Study 1 indicate that 2 mg of atropine combined with 600 mg of 2-PAM had significant effects on the subjective feelings, mood states, and temperament patterns of the soldiers. When combined with heat exposure, however, the drug reactions were intensified beyond those noted under the more comfortable conditions. The observed effects can be reasonably associated with heat exposure and omission of lunch, but those conditions were not severe enough to interfere seriously with performance. The ESQ, POMS, and BSRS inventories effectively reflected the moderate changes that occurred in subjective reactions due to the drugs, and they showed subjective response to both drug and heat stress.

STUDY 2. EFFECTS OF ATROPINE/2-PAM AND HEAT ON SYMPTOMATIC, MOOD, AND SUBJECTIVE REACTIONS WHILE WEARING THE MOPP-IV ENSEMBLE

Method

Participants. Eight male soldier volunteers not used in Study 1, ages 18 to 22 years, were screened as described earlier. They were also briefed and signed a volunteer agreement of informed consent.

Procedure. Study 2 used the same procedures as Study 1, except that, throughout all training and testing, the soldiers wore the complete MOPP-IV ensemble (including a charcoal-impregnated jacket and trousers,

overboots, mask, hood, and gloves) over the BDU. To offset the additional heat load due to wearing the MOPP-IV system, the ambient temperature of the no-heat control condition was reduced from 70 °F (21.1 °C) with 30% RH (as used in Study 1) to 55 °F (12.75 °C) with 30% RH. The soldiers were allowed drinking water ad lib from standard military canteens, but they were required to use the standard drinking tube accessory of the mask to avoid breaking the protective seal of the MOPP-IV ensemble. As in Study 1, lunch and snacks were not allowed.

Results and Discussion

The overall stress effects of the test conditions involving 95 °F (35 °C) temperatures in this study proved so severe that only one soldier was able to complete Cycle 2, and no one was able to begin Cycle 3. This contrasts sharply with Study 1, in which all soldiers completed testing under all conditions when wearing only the BDU.

ESQ The overall incidence of reported symptoms on the ESQ was surveyed in the same manner as in Study 1. The group means for the new control condition were arrayed in descending magnitude and were used as the optimum basis for comparison. The group mean ratings for the four test conditions are summarized in Table 2, along with short statements of the respective items. As in Table 1, Table 2 lists only mean item ratings of 1.00 or higher for the three stressful conditions. Thus, Tables 1 and 2 are parallel representations of the ESQ data for the BDU and MOPP-IV conditions, respectively.

A comparison of Tables 1 and 2 shows that, under the same testing conditions, soldiers reported many more symptoms while wearing MOPP-IV than they did while wearing BDU. This clearly demonstrates that wearing MOPP-IV by itself resulted in significant adverse subjective and symptomatic reactions.

Inspection of Table 2 indicates high ESQ ratings on items reflecting symptoms traditionally attributed to atropine, for example, dry mouth (Item 49) and thirsty (Item 55). Some visual symptoms, such as dim vision (Item 6), eyes irritated (Item 40), and blurry vision (Item 41), were also reported, with highest ratings being found, generally speaking, in test conditions involving the drug. Headache (Item 2) was prominent under the heat conditions; other heat effects are evidenced by high ratings on felt warm (Item 30), feet sweating (Item 32), and sweating all over (Item 33). Symptoms probably associated with upper nervous system effects, for example, lightheaded (Item 1), dizzy (Item 4), and faint (Item 5), occurred under both the drug and the drug and heat condition. The severity of the drug and/or heat effects under MOPP-IV is evident in the high number of

TABLE 2
Group Mean Ratings on ESQ Items for Each Task Condition With MOPP-IV

Item No.	Description of Item	Group Mean Ratings: 55 °F (12.7 °C) 30% RH Control	55 °F (12.7 °C) 30% RH Drug Only	95 °F (35 °C) 60% RH Heat Only	95 °F (35 °C) 60% RH Drug and Heat
68	I was hungry	3.25	2.75	2.12	2.50
67	I felt good	2.62	2.00	1.50	
66	I felt alert	2.37	2.25	2.50	2.12
57	I felt sleepy	1.87	2.87	1.00	2.37
56	I felt tired	1.62	2.87	1.12	2.50
34	My hands were cold	1.00			
22	My back ached	0.87	1.25		1.87
7	Coordination was off	0.87	1.00	1.50	1.62
64	I was bored	0.75	1.25		
36	I felt chilly	0.75			
2	I had a headache	0.75		3.37	2.87
44	I could not hear well	0.75			1.00
51	I was coughing	0.75			1.12
49	My mouth was dry	0.62	4.12		3.87
12	Heart was pounding	0.62		2.50	2.00
30	I felt warm	0.62		4.00	3.25
59	Concentration was off	0.62			1.62
55	I was thirsty	0.62	2.62	1.87	4.00
46	My nose felt stuffed up	0.50			
62	I felt irritable	0.50			1.50
58	I could not sleep well	0.50			
63	I felt restless	0.37		1.25	1.62
16	I had a muscle cramp	0.37	1.75		2.25
29	Urinate less than usual	0.37			
35	My feet were cold	0.37			
20	My legs or feet ached	0.37	1.12		2.25
50	My throat was sore	0.37	1.37		1.37
41	My vision was blurry	0.25	1.87	1.00	2.50
4	I felt dizzy	0.25	1.00	2.12	2.25
18	Muscles tight or stiff	0.25	1.50		2.00
11	Heart was beating fast	0.25		2.50	2.25
9	It was hard to breathe	0.25		2.50	2.62
47	I had a runny nose	0.25		1.50	
6	My vision was dim	0.25	1.37		1.87
3	I felt sinus pressure	0.25			
60	Was more forgetful	0.25			1.25
1	I felt lightheaded	0.25		1.50	2.50
15	Hands shaking or trembling	0.25		1.00	1.37
40	My eyes felt irritated	0.25		1.62	2.12
61	Felt worried/nervous	0.25			1.00
28	Urinate more than usual	0.12			

(Continued)

TABLE 2 *(Continued)*

Item No.	Description of Item	Group Mean Ratings: 55 °F (12.7 °C) 30% RH Control	55 °F (12.7 °C) 30% RH Drug Only	95 °F (35 °C) 60% RH Heat Only	95 °F (35 °C) 60% RH Drug and Heat
65	I felt depressed	0.12			
45	My ears were ringing	0.12			
25	I had gas pressure	0.12			
32	My feet were sweaty	0.12		2.25	2.25
8	I was short of breath	0.12		2.62	2.37
33	Sweating all over	0.12		4.37	4.00
26	I had diarrhea	0.00			
37	I was shivering	0.00			
19	I felt weak	0.00		1.75	2.00
39	Skin burning or itchy	0.00			
17	I had stomach cramps	0.00		1.00	1.37
27	I felt constipated	0.00			
24	Felt sick to stomach	0.00		1.25	2.37
14	I had chest pressure	0.00			
13	I had a chest pain	0.00		1.25	
42	Ears blocked up	0.00			
43	My ears ached	0.00			
10	It hurt to breathe	0.00			
38	Parts of body numb	0.00			
21	Hand/arm/shoulder ache	0.00			1.00
23	I had a stomachache	0.00		1.00	1.75
48	I had a nose bleed	0.00			
5	I felt faint	0.00		1.37	1.62
52	I lost my appetite	0.00			
53	I felt sick	0.00		1.00	2.50
54	I felt hungover	0.00			
31	I felt feverish	0.00		1.00	1.50

Note. Only ratings of 1.00 or greater are shown for the drug only, heat only, and drug and heat conditions.

body discomfort symptoms: chest pain (Item 13), hands shaking (Item 15), muscle cramps (Item 16), stomach cramps (Item 17), muscles stiff/tight (Item 18), hands/arms/shoulders ache (Item 21), backache (Item 22), stomachache (Item 23), feverish (Item 31), sore throat (Item 50), coughing (Item 51), felt sick (Item 53), and tired (Item 56). General negative feelings and mood reactions were also frequent during the MOPP-IV conditions, for example, coordination off (Item 7), tired (Item 56), worried (Item 61), irritable (Item 62), restless (Item 63), and bored (Item 64). Hunger feelings (Item 68) were reported again, probably due to the omission of lunch.

POMS. The individual subjective ratings on the POMS were collated, and separate two-way ANOVAs for repeated measures were conducted on each of the scales. The results of these analyses indicated significant main effects (due to administration of the drug) for tension, $F(1, 7) = 7.06$, $p < .05$, and for depression, $F(1, 7) = 7.08$, $p < .05$. Significant main effects due to temperature were obtained for tension, $F(1, 7) = 20.59$, $p < .01$, depression, $F(1, 7) = 11.05$, $p < .02$, fatigue, $F(1, 7) = 13.35$, $p < .01$, and confusion, $F(1, 7) = 6.57$, $p < .05$. Significant Drug × Temperature interactions were also obtained for depression, $F(1, 7) = 10.75$, $p < .02$, and confusion, $F(1, 7) = 11.53$, $p < .02$. Thus, the drug condition led to feelings of tension and depression; the heat condition led to feelings of tension, depression, fatigue, and confusion; and the drug and heat condition resulted in the highest incidence of depression and confusion.

BSRS. The individual subjective ratings on the BSRS were collated, and separate three-way ANOVAs for repeated measures were conducted on each of the scales. The results of these analyses indicated a significant main effect of drug on tiredness, $F(1, 7) = 87.62$, $p < .001$, as well as significant main effects of temperature on tiredness, $F(1, 7) = 5.91$, $p < .05$, discomfort, $F(1, 7) = 155.68$, $p < .001$, and warmth, $F(1, 7) = 112.87$, $p < .001$. A significant Drug × Temperature interaction was obtained for warmth, $F(1, 7) = 6.38$, $p < .05$. In addition, the effects of continued heat exposure were reflected by significant effects for cycle on tiredness, $F(3, 21) = 17.67$, $p < .001$, and discomfort, $F(3, 21) = 17.52$, $p < .001$. These were coupled with significant Temperature × Cycle interactions for tiredness, $F(3, 21) = 16.60$, $p < .001$, and discomfort, $F(3, 21) = 8.94$, $p < .001$.

The findings of Study 2 indicate that the much greater heat load generated by wearing the MOPP-IV ensemble oriented the soldiers' symptomatic reactions toward the excessive heat conditions as well as toward the effects of the drugs. The significant reactions of tiredness and discomfort were consistent with the responses to heat, and they are what one would expect with continued exposure to these stressful conditions.

To get some indication of the subjective reactions of the soldiers during the period prior to their removal from the study, an additional analysis of the BSRS data for Cycle 1 was also performed. The ESQ and POMS could not be included in this analysis, because they were administered only once at the end of each test day. The results of this analysis showed significant main effects due to temperature on warmth, $F(1, 7) = 37.19$, $p < .001$, and on discomfort, $F(1, 7) = 79.55$, $p < .001$. These findings indicate that the soldiers were developing early symptomatic reactions to the heat conditions as early as Cycle 1, even though they were otherwise still operational. These

reactions correspond to the later, more severe, heat reactions that occurred in Cycle 2.

Table 3 summarizes the individual exposure duration times and symptoms of the soldiers in Study 2 who either voluntarily withdrew or were removed. It can be seen that in both conditions involving heat, half of the soldiers voluntarily withdrew, and the remaining solders were removed by the medical monitor because they showed signs and symptoms of impending heat illness. Furthermore, the exposure times in the heat and drug condition (M = 149.25 min; SD = 39.93) were shorter than in the heat-only condition (M = 183.63 min; SD = 29.74). The difference between these group mean endurance times was found to be significant, based on a Student's t test for paired data, $t(7) = 3.11$, $p < .02$. Thus, it appears that although the overall effects of drug were secondary to those of heat in this study, one dose of

TABLE 3
Exposure Durations and Symptoms of MOPP-IV Participants Who Withdrew or Were Removed

Exposure Time (Minutes)	*Withdrew/ Removed*	*Symptoms*
	Heat Only Condition (8 of 8 Withdrew/Removed)[a]	
236	Removed	Rectal temperature criteria exceeded
198	Withdrew	Dizzy, severe nausea
194	Removed	Chest pressure, heart pounding, felt "really weird"
190	Removed	Dizzy, heart pounding (high heart rate)
186	Withdrew	Headache, dizzy, stomach cramps
185	Removed	Hyperventilating
149	Withdrew	Severe headache (head "exploding")
131	Withdrew	Could not breathe, "lungs bursting"
	Heat and Drug Condition (8 of 8 Withdrew/Removed)[b]	
252	Removed	Rectal temperature criteria exceeded
156	Removed	Heart rate criteria exceeded
137	Withdrew	Too hot, felt about to hyperventilate
135	Withdrew	Headache, dizzy, lightheaded, felt sick to stomach
134	Removed	Heart rate criteria exceeded
130	Withdrew	Specific reason unclear, unsteady
128	Withdrew	Headache, dizzy, lightheaded, felt sick to stomach
122	Removed	Unsteady (assistance needed), dizzy, dozing off during tests
	Drug Only Condition (1 of 8 Withdrew/Removed)	
241	Removed	Dizzy, chilly, feeling "woozy" (suspected hypoglycemia)

[a] M = 183.63 min, SD = 29.74. [b] M = 149.25 min, SD = 39.93.

atropine/2-PAM still effectively reduced the endurance times of the soldiers who were exposed to severe heat combined with MOPP-IV. In contrast, only one removal occurred during the drug-only condition, and this case was hypothesized by the medical monitor to be due to hypoglycemia.

There was only one incident in this study of hyperventilation due to heat, and there were no anxiety attacks or claustrophobic reactions such as those reported by Brooks, Xenakis, Ebner, and Balson (1983). This is counter to concerns expressed by Brooks et al. about possible encapsulation effects due to the MOPP-IV ensemble, based on their findings in a field training exercise requiring soldiers to wear the MOPP-IV ensemble for only 1 hr. Despite that short time, 3 of 70 soldiers (4.3%) had to be removed within the first 10 min due to negative psychological reactions (e.g., anxiety, panic, hyperventilation, visual distortions, and fear of dying), and at least 20% of the participants showed "negative psychological reactions as manifested by gross symptoms" (Brooks et al., 1983, p. 234) that required intervention by medical personnel. Carter and Cammermeyer (1985a) reported a similar attrition rate in another field study requiring soldiers to wear MOPP-IV for 2.5 hr. In that study, 5 out of 105 soldiers (4.8%) dropped out because of hyperventilation, claustrophobia, headache, dizziness, inability to tolerate the mask, confusion of time judgment, and tremors. However, in a later 3-day field study involving soldiers wearing MOPP-IV, Carter and Cammermeyer (1985b) obtained results that did not correspond either to their own previous findings or to those of Brooks, et al. (1983), in that only 5 out of 195 soldiers (2.6%) had to be removed. Furthermore, none of the five had to be removed until the evening of the second day, each one a heat casualty. In contrast, no extreme psychological reactions or anxiety attacks were observed in the present study, even though symptoms of heat illness occurred in Study 2, and no one was able to complete 6 hr of heat exposure while in MOPP-IV gear. Therefore, we conclude that the reactions observed by Brooks et al. (1983) and by Carter and Cammermeyer (1985a) are probably rare occurrences. Nevertheless, this area needs further study, especially because others (e.g., see Gorman, et al., 1988; Morgan, 1983) have cited evidence suggesting that the wearing of gas masks may trigger disordered breathing and panic reactions in individuals who possess certain personality attributes.

SUMMARY

In two studies of subjective reactions to exposure to ambient heat at 95 °F (35 °C) with 60% RH and a single dose of nerve agent antidote (i.e., 2 mg of atropine sulfate and 600 mg of 2-PAM), it was found that:

1. In ambient heat, all participants were able to complete 6 hr of testing when wearing the BDU, but only 2 hr when dressed in MOPP-IV chemical protective clothing.
2. Reported symptoms were due primarily to ambient heat rather than to atropine/2-PAM.
3. Elevated heat stress, caused by wearing the MOPP-IV ensemble in ambient heat, significantly increased the frequency and severity of reported symptoms compared to equivalent conditions using the BDU.
4. Effects of atropine/2-PAM were increased by severe heat combined with MOPP-IV, resulting in significantly shorter endurance times.
5. Claustrophobic and anxiety reactions due to encapsulation in MOPP-IV, as reported in other studies, were not observed under any of the conditions tested.

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Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on use of volunteers in research.

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